EXPERIMENTAL DETERMINATION OF CONVECTIVE HEAT TRANSFER COEFFICIENT IN WIRE ELECTRO DISCHARGE MACHINING

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

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Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

Wire electro discharge machining (WEDM) is a fully extended and competitive machining process widely used to produce dies and moulds. However, the risk of wire breakage affects adversely the full potential of WEDM since the overall process efficiency is considerably reduced. These symptoms are especially related to the occurrence of an increase in discharge energy, peak current, as well as increases or decreases in ignition delay time. Because of that, an experimental determination method of the convective heat transfer coefficient in wire electro discharge machining is introduced to prevent the wire breaks during running the machine. Parameters such as peak current and flushing pressure are studied. A special device is developed to measure the average temperature increment of the wire after a period of short circuit discharges, and the thermal load imposed on the wire is also tracked and recorded in advance. Then, based on the thermal model of the wire, the convective coefficient can be calculated accurately. Some tuning experiments are carried out inside and outside a previously cut profile to examine the influence of the kerf on the convective coefficient. With this method, the effect of the coolant flushing pressure on the convective coefficient can be estimated. Based on the results of the analyses, this paper contributes to improve the process performance through a wire breakage.

ABSTRAK

Mesin wayar nyahcas elektrik (WEDM) adalah mesin yang sangat kompetitif dan digunakan secara meluas dalam menghasilkan acuan. Walau bagaimanapun, risiko pemutusan wayar memberi kesan kepada potensi WEDM apabila keseluruhan kecekapan proses semakin berkurangan. Simptom ini berkaitan dengan kejadian peningkatan nyahcas tenaga, arus yang tinggi dan juga peningkatan serta pengurangan penangguhan masa nyalaan percikan elektrik. Oleh sebab itu, eksperimen kaedah penentuan pemalar peralihan haba secara perolakan dalam WEDM diperkenalkan bagi mengelakkan pemutusan wayar berlaku semasa mengendalikan mesin. Faktor pengehad seperti arus dan tekanan simbahan penyejuk juga dikaji. Purata kenaikan suhu wayar selepas nyahcas litar pintas dan beban haba yang dikenakan pada wayar dicatat. Kemudian berdasarkan model haba, pemalar perolakan haba dapat di tentukan dengan tepat. Beberapa eksperimen dijalankan untuk mengkaji kesan laluan pemotongan bahan ke atas pemalar peralihan haba secara perolakan. Tekanan simbahan penyejuk juga digunakan semasa eksperimen dan kesan tekanan simbahan ini ke atas pemalar peralihan haba secara perolakan juga dikaji.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

h	Convective heat transfer coefficient, W/ (m^{2}K)
x	Coordinate along wire axis, m
t	Time coordinate, s
T	Temperature increment along the wire at any time, K
ρ	Mass density, kg/m^3
c	Specific heat, J/(kg K)
Vw	Wire transporting speed, m/s
λ	Thermal conductivity of wire material, W/(m K)
av	Thermal diffusivity of wire material, m^2/s
L	Circumference of the wire, m
S	Cross section area of the wire, m^2
n	= hL/S
$q^{'''}$	Heat flux density, W/m
$q^{'''}_{J}$	Joule heat flux density, W/m
$q^{'''}_{d}$	Discharge heat flux density, W/m
x_1, x_4	Coordinates of the current supplying positions
x_2, x_3	Coordinates of the top and bottom edge of the workpiece
ΔTa	Average temperature increment, K
r	Radius of the wire
$I_S(t)$	Value of the short circuit current, A

ts	Period of the discharging current pulse, s
$U_1(t)$	Output voltage of current sensor, V
R_1	Resistance of the series resistor, Ω
Ip	Peak current of the pulse, A
Q_1	Number of turns of the coil
α	Temperature coefficient of wire material, K^{-1}
U_O	Output voltage of the resistance measuring system, V
R	Resistance of the wire electrode between x_1 and x_4, Ω
Ic	Constant current, A
β	Amplification of the differential signal amplifier
ω	Cross section area of the wire, m^2

LIST OF ABBREVIATIONS

WEDM	Wire electro discharge machining
AISI	American iron steel institute

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Wire electrical discharge machining (WEDM) is an adaptation of the basic EDM process, which can be used for cutting complex two and three dimensional shapes through electrically conducting materials. WEDM utilizes a thin, continuously moving wire as an electrode [10]. It is a relatively new process and applications have grown rapidly, particularly in the tool making field. The wire electrode is drawn from a supply reel and collected on a take up reel. This continuously delivers fresh wire to the work area. The wire is guided by sapphire or diamond guides and kept straight by high tension, which is important to avoid tapering of the cut surface [6]. High frequency dc pulses are delivered to the wire and workpiece, causing spark discharges in the narrow gap between the two. A stream of dielectric fluid is directed, usually coaxially with the wire, to flood the gap between the wire and the workpiece [7]. The power supplies for WEDM are essentially the same as for conventional EDM, except the current carrying capacity of the wire limits currents to less than 20A, with 10A or less being most normal. WEDM is most commonly used for the fabrication of press stamping dies, extrusion dies, powder composition dies, profile gages and templates [10].

1.2 PROBLEM STATEMENT

In WEDM process, the heat generated by continuous discharges will lead to the temperature increment and local erosion of the wire and consequently lower its tensile strength. Contradictorily, it is necessary to keep the wire tension at high level in order to guarantee the machining accuracy. To prevent the wire from breaking, the machining processes must take place in ionized water bath which not only aids in the sparking mechanism, but also helps cooling the wire. The accurately determined convective heat transfer coefficient will lead to exact analysis and hence will be helpful for the prediction of the wire breakage.

1.3 PROJECT OBJECTIVES

The objectives of this project :

i) To determine the convective heat transfer coefficient in WEDM.

ii) To discover the effect of the kerf on the convective coefficient.

iii) To investigate the effect of the flushing pressure on the convective coefficient.

1.4 PROJECT SCOPES

This project concentrates on determining the convective heat transfer coefficient in WEDM using brass wire material with diameter 0.2mm. The workpiece use in this project is AISI 4140 with diemension (200mm x 40mm x 15mm). The values of the convective coefficient change with the kerf conditions and in the presence of coolant flushing pressure.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION OF WEDM

Wire-electro discharge machining is a process of material removal of electrically conductive materials by the thermo-electric source of energy [3]. The material removal by controlled erosion through a series of repetitive sparks between electrodes, workpiece and tool. The electrode is a thin wire and it is pulled through the workpiece from a supply spool onto a take up mechanism [2,3]. On application of a proper voltage, discharge occurs between the wire electrode and the workpiece in the presence of a flood of deionized water of high insulation resistance[4]. WEDM using small diameter wires permits extremely narrow slots to be machined in the workpiece, and the kerf is only slighter wider than the wire diameter.

Figure 2.1 Wire Electro-Discharge Machining [4]

2.2 WEDM FUNCTION

WEDM has advanced quickly with the addition of computer numerical control (CNC). Today WEDM is used for a wide variety of precision metalworking applications which would have been almost impossible just a few years ago [8]. Cutting tolerances, cutting speeds and surface finish quality have been greatly improved [11]. Wire-cut EDM can do things older technologies cannot do as well, as quickly, as inexpensively, and as accurately. Most parts can now be programmed and produced as a solid, rather than in sections and then assembled as a unit that necessary. The WEDM is capable of producing complex shapes such as tapers, involutes, parabolas and ellipses that would otherwise be difficult to produce with conventional cutting tools [14,15].

2.3 WEDM OPERATING SYSTEM

Figure 2.2 below shows the basic operating of the WEDM machine. The WEDM move the workpiece along the X and Y axes (backward, forward, and sideways) in a horizontal plane toward a vertically moving wire . During the cutting action, an arc gap of 0.02mm to 0.05mm is maintained between the workpiece and the wire electrode [7]. The eroded material caused by the spark is then washed away by the dielectric fluid. The WEDM process, as shown in Figure 2.2 also generates the desired shape by using electrical sparks between a thin, traveling brass wire electrode and workpiece to erode a path in the workpiece material [6,7]. It also shows continuous electrical sparks being generated between the wire and workpiece for material removal. The cutting force generated in WEDM is small, which makes it suitable for manufacturing miniature features and micro-mechanical components [7].

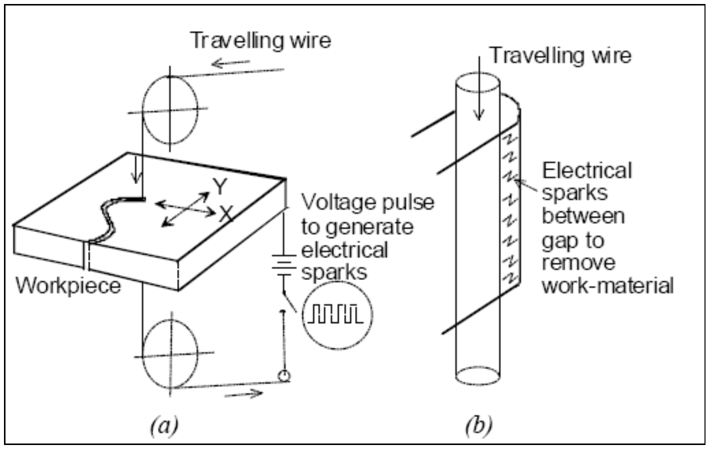

Figure 2.2 Conventional 2D WEDM operation [2]

2.3.1 Operation Panel

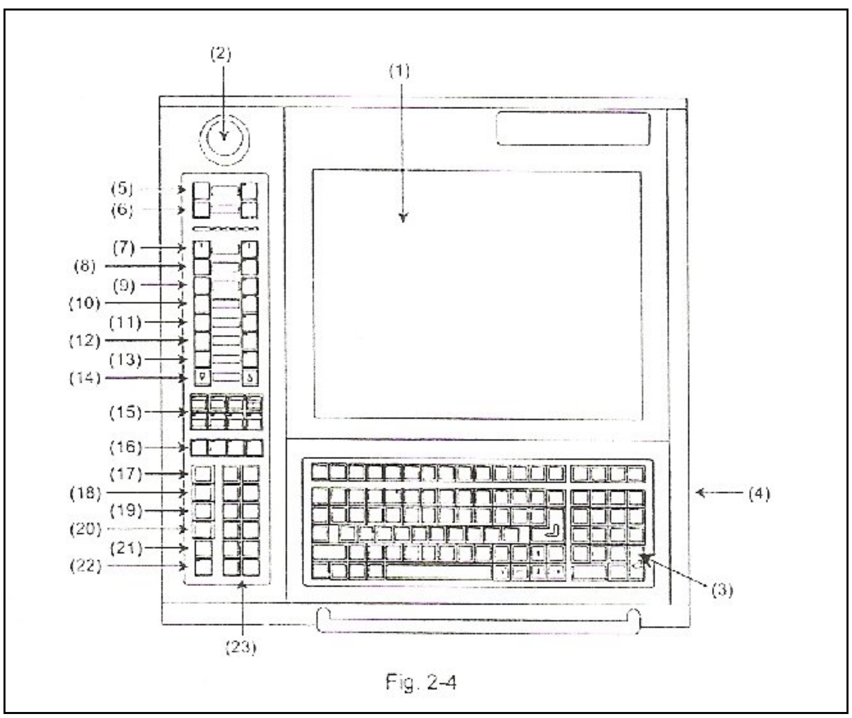

Figure 2.3 Operation panel of WEDM [2]

(1)	LCD screen	(13)	[TANKDRAIN ON/OFF]
(2)	Emergency stop switch	(14)	[TANK DOOR]
(3)	Keyboard	(15)	Switches [A0] to [A7]
(4)	Floppy disc drive	(16)	[MFR0] to [MFR3]
(5)	[SOURCE ON/OFF] switches	(17)	[OFF] switch
(6)	[POWER ON/OFF] switches	(18)	[ACK] switch
(7)	[AWT CUT/TREAD] switch	(19)	[HALT] switch
(8)	[TENSION ON/OFF] switches	(20)	[ENT] switch
(9)	[WIRE STOP/RUN] switches	(21)	[ST] switch
(10)	[HIGH PRESSURE ON/OFF] switches	(22)	[UV] switch
(11)	[LOW PRESSURE ON/OFF] switches	(23)	Jog switches
(12)	[TANK FILL ON/OFF]		

2.3.2 Dielectric Fluid

One of the most important factors in a successful WEDM operation is the removal of the particles (chips) from the working gap. Flushing these particles out of the gap with the dielectric fluid will produce good cutting conditions, while poor flushing will cause erratic cutting and poor machining conditions [10].

The dielectric fluid in the WEDM process is usually deionized water. This is tap water that is circulated through an ion-exchange resin. The deionized water makes a good insulator, while untreated water is a conductor and is not suitable for the electrical discharge machining process[11,13]. The amount of deionization of the water determines its resistance. For most operations, the lower the resistance the faster will be the cutting speed [10].

The dielectric fluid used in the WEDM process serves several functions :

1. It helps to initiate the spark between the wire and the workpiece [2].
2. It serves as an insulator between the wire and the workpiece [2].
3. It flushes away the particles of disintegrated wire and workpiece to prevent shorting [3].
4. It acts as a coolant for both the wire and the workpiece [3].

2.4 MILLING MACHINE

A milling machine is a machine tool used for the shaping of metal and other solid materials. Its basic form is that of a rotating cutter which rotates about the spindle axis (similar to a drill), and a table to which the workpiece is affixed. In contrast to drilling, where the drill is moved exclusively along its axis, the milling operation involves movement of the rotating cutter sideways as well as in and out [14].

The cutter and workpiece move relative to each other, generating a tool path along which material is removed. The movement is precisely controlled, usually with slides and lead screws or analogous technology [13]. Often the movement is achieved by moving the table while the cutter rotates in one place, but regardless of how the parts of the machine slide, the result that matters is the relative motion between cutter and workpiece. Milling machines may be manually operated, mechanically automated, or digitally automated via CNC [14].

Milling machines can perform a vast number of operations, some of them with quite complex tool paths, such as slot cutting, planing, drilling, diesinking, rebating and routing. Cutting fluid is often pumped to the cutting site to cool and lubricate the cut, and to sluice away the resulting swarf.[14].

Figure 2.4 Milling machine [14]

Most CNC milling machines or machining centers are computer controlled vertical mills with the ability to move the spindle vertically along the Z-axis. This extra degree of freedom permits their use in die sinking, engraving applications, and 2D surfaces such as relief sculptures [13]. When combined with the use of conical tools or a ball nose cutter, it also significantly improves milling precision without impacting speed, providing a cost-efficient alternative to most flat-surface hand-engraving work [11].

CNC machines can exist in virtually any of the forms of manual machinery, like horizontal mills. The most advanced CNC milling-machines, the 5-axis machines, add two more axes in addition to the three normal axes (XYZ). Horizontal milling machines also have a C or Q axis, allowing the horizontally mounted workpiece to be rotated, essentially allowing asymmetric and eccentric turning [13]

2.5 MATERIALS

2.5.1 Wire Materials

The wire material used in this project is made of brass, which is an ideal material for the thermal resistance. It is an alloy of copper and zinc that has good corrosion resistance and is easily formed, machined and cast [9]. Copper is the main component, and brass is usually classified as a copper alloy. The color of brass varies from a dark reddish brown to a light silvery yellow depending on the amount of zinc present. The more zinc, the lighter the color. Brass is stronger and harder than copper, but not as strong or hard as steel [6]. It is easy to form into various shapes, a good conductor of heat, and generally resistant to corrosion from salt water. Because of these properties, brass is used to make pipes and tubes, weather-stripping and other architectural trim pieces, screws, radiators, musical instruments, and cartridge casings for firearms [9]. It has consistent tensile strength which is the heat treated for stable tensile strength to avoid the wire breakage [1].

Figure 2.5 Brass material [3]

2.5.2 Mechanical Properties of Brass Wire

Table 2.1 : Compositon of Brass [12]

Component	Wt.%
C	60 - 63
Zn	35.5
Pb	2.5 - 3.7
Fe	Max 0.35
Other	Max 0.5

Brass consists of five elements which copper has the highest percentage of the composition. The percentage is between 60 to 63 percent and it follows by zinc. The percentage of zinc element in brass is 35.5 percent and follows by lead 2.5 to 3.7 percent, iron 0.35 percent and other element is 0.5 percent [12].

Table 2.2 : Mechanical Properties of Brass [12]

Mechanical Properties	Metric
Ultimate Tensile Strength	338 – 469 Mpa
Tensile Strength, Yield	124 – 310 Mpa
Elongation at Break	53%
Modulus of Elasticity	97 Gpa
Bulk Modulus	140 Gpa
Poisson’s Ratio	0.31
Machinability	100%
Shear Modulus	37 Gpa

Table 2.2 shows mechanical properties of brass. Brass has Ultimate Tensile Strength between 338 to 469 Mpa and Tensile Strength , Yield varies from 124 to 310 Mpa. The elongation at break is 53%, Modulus of Elasticity 97 Gpa and Bulk Modulus is 140 Gpa. The Poisson’s Ratio of brass is 0.31, Shear Modulus 37 Gpa and it has 100% machinability [12].